breaking down and being carried away. This suggestion fits the association observed between patches of cuspate surfaces and adjacent obstacles. It does not seem entirely consistent with this theory that dirtless polygons were found near Crossfell's summit in March 1953 during calm, dry, cold conditions. However, although the weather at Alston was calm, the mountain summit undoubtedly had some air movement, and ablation in the dry air of that month would have been by evaporation from the solid state. The concentric rings showing stratification sometimes revealed in these polygons also suggests evaporation, for melting in warm air would destroy the effect.

Having developed a theory for the ablation polygon it is necessary to explain the frequent association of the dirt fringe—a feature of remarkable clarity when the phenomenon reaches its best development. To explain this the process described by Ball[5] seems to be entirely convincing and satisfactory. This may be called the "normal-trajectory" theory. It suggests that by assuming that the trajectory of dirt particles is normal to the surface as ablation continues, dirt which is initially uniformly distributed tends to become concentrated along the ridges. The theory is largely confirmed by the observation that leaves of grass and heather, originally lying at random on the surface, tend to move to the adjacent ridge by being twisted to lie along it.

Conclusion

After a reconsideration of all the observations and theories assembled it is suggested that turbulence in the lee of surrounding obstacles accounts for ablation polygons, and that the "normal trajectory" theory of dirt motion on an ablating snowbed explains the dirt fringes. The "turbulence" theory concerning polygon development is especially suspect but both aspects of the phenomenon require verification by further observation or experiment. Up to date experimental approaches using smoke to observe air currents, and hair-dryers applied to sooty snow surfaces to synthesis polygons, have failed to show any results. There is still a need for careful observations from this country and abroad if the complexities of these fascinating features are to be completely solved.

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NOTES ON THE FORMATION OF OGIVES AS PRESSURE WAVES

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Based on the observations and velocity measurements on the Mt. Collon glacier, it was shown that during the time of ablation large local increases in velocity can arise, which were taken to be the cause for the formation of pressure waves[1]. In the report quoted below, the reason for the astonishing local acceleration of the movement in July, i.e., at the time of strongest ablation, was thought to lie in the increased amount of melt water and in the resulting reduction of friction on the glacier face[2].

Since the measurements of J. D. Forbes (1842–43) on the Mer de Glace and of L. Agassiz on the Unteraar Glacier (1845–46) it has been known that the flow velocity in the ablation area is often very much higher in summer than in winter. For example, Agassiz found in a profile of the Unteraar Glacier, at that time 6800 m. from the glacier snout, that the minimum winter velocity (January) amounted to only 36 per cent of the highest summer velocity. On the other hand, R. Blümke and S. Finsterwalder ascertained that on the Hintereisferner conditions in the firn area were exactly the reverse, in that there the velocity measured in summer was smaller than the average yearly velocity[3,4]. These observations were confirmed by the more recent velocity measurements on the Claridenfirn (Streiff-Becker) as well as on the Jungfraufirn[5].

The yearly velocity variation in the ablation area may well be brought about almost solely through the change of slip velocity on the glacier bed. Lack of melt water in winter is doubtless the reason for a decrease in the component of slip.

In judging the specific friction between ice and rock influence of intergranular water pressure at the surface of contact must be considered, where the following equation as advanced by K. Terzaghi can logically be applied[6]:

$$s=(p-u) \cdot tg\ \phi,$$

where s=shear resistance or specific friction in the sliding surface
p=total normal pressure at the sliding surface
u=intergranular water pressure
ϕ=effective angle of friction. (Internal friction or friction in contact zone)

If $u=p$
$s=0$ which, as is well known, leads to the outbreaks of the glacial lakes which are so much the cause of apprehension.

Experiments on ogives should therefore, if possible, run parallel with water run-off measurements at the glacier snout. A large amount of melt water in the summer causes an increase in intergranular water pressure at some of the less permeable places in the slip plane and therewith a reduction in friction between the ice and rock. The lubricating effect of the water may thus become specially noticeable on steep steps. The difference in velocity between the steep slope and its base therefore increases during the time of ablation and causes a pressure wave on account of the plastic transverse expansion of the ice mass, which gives way upwards. If the magnitude and rhythm of the differences in velocity, or of the specific deformation (strain) due to lengthwise compression are known, then the transverse expansion, or the wave height and wave length can be formulated. Furthermore, the longitudinal pressures causing the wave formation may be estimated if the rheological properties of the ice are known. Thus for example longitudinal pressures in the range of 10 kg./cm.^{2} were calculated, based on the maximum shrinkage of 1·4 per cent per day measured in the upper ice tunnels of the Mt. Collon glacier (see also J. W. Glen[8]).

Dr. Cuchlaine King and J. D. Ives have observed in Iceland not only annual ogives but also ogives of a similar type with smaller features[7]. From this it can be deduced that variations in longitudinal pressure below steep slopes can have different causes with quite different rhythms. The attached photograph, Fig. 1 (p. 29), of the steep step of the Mayangdi Glacier (1953) made available by the Swiss Dhaulagiri Expedition of the Akademische Alpen Klub, Zürich, may serve as a further example.

This shows that smaller waves, which are evidently connected with crevasse formation, lie above the long pressure waves, the regularity of which points to an annual rhythm. It will be noticed that these secondary waves tend to decrease more and more the greater the distance from the steep slope. Another beautiful example of annual ogives is to be found in the Trift Glacier[9, 10].

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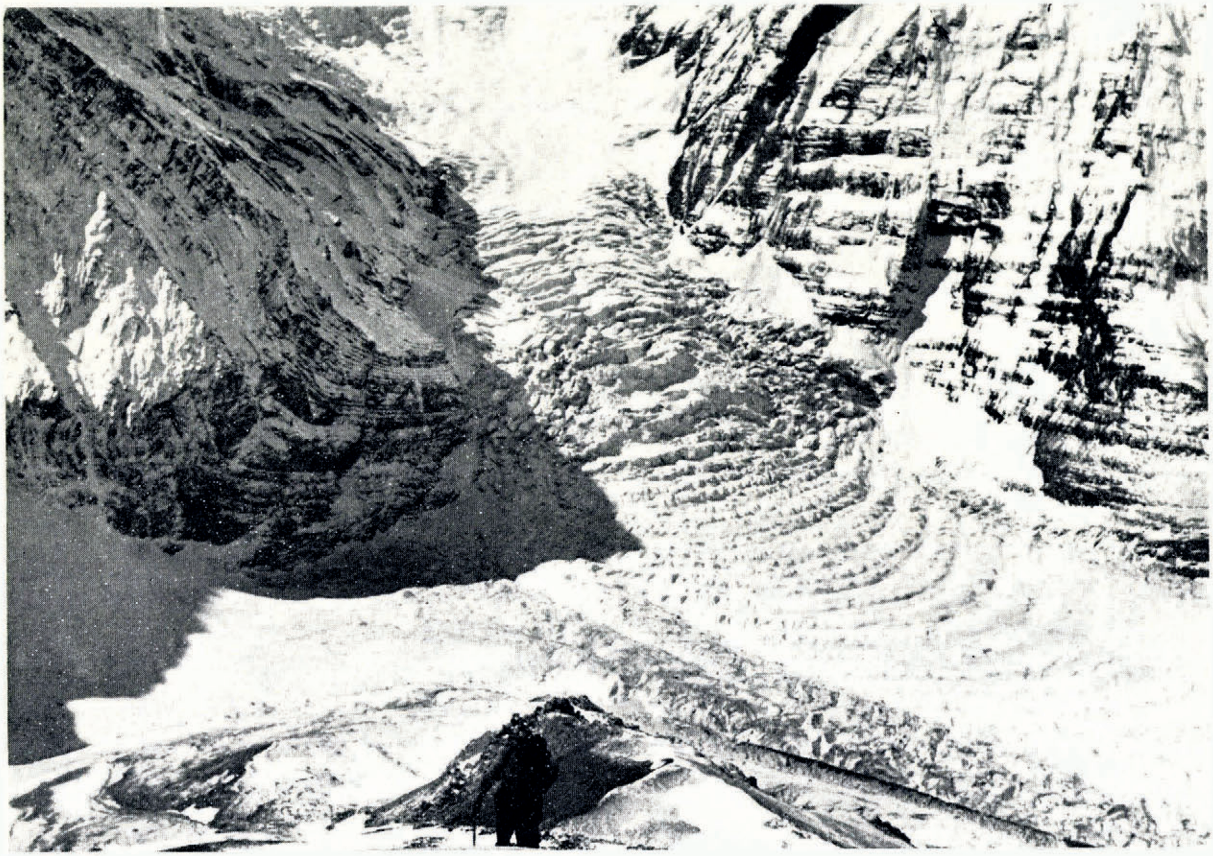

Steep fall on the Mayangdi Glacier (Dhaulagiri) below the north-east col, 1953

(Photograph by Dr. R. Pfisterer.)